

1.11 *Construction management and engineering personnel shall demonstrate a familiarity level knowledge of the principles and concepts of natural phenomena hazards.*

Supporting Knowledge and/or Skills

a. *Discuss the impact on facilities, and the mitigating factors, associated with the following hazards:*

- Flooding
- Wind
- Tornado
- Earthquake and/or other seismic events

Flooding

From a design basis standpoint, the design criteria for structures, systems, and components (SSC) impacted by flooding are water damage, hydrostatic pressure on walls and roofs, and dynamic effects of erosion (shear), wind-wave action, and debris loads/impacts.

In a flooding event, the impact on facilities are the results of submergence, hydrostatic loads, and dynamic loads. Submergence principally impacts the internal components of a facility, causing loss of electrical power, failure of containment of radioactive or hazardous materials; it may render the facility unfit for future operation. Foundation settling may also occur. Hydrostatic loads must be considered in design of exterior walls located below the design basis flood level. Dynamic loads must be considered in the impact of wind-waves, ice flows, and debris, as well as erosion of foundations and protective dikes and levees.

For new facilities the easiest method to avoid a flooding event is to select a site above the design basis flood level, based on analysis of the probability of an initiating event: river flooding, dam or dike failure, storm surge, etc. To mitigate the impact of local precipitation, both sites and facilities should be designed for adequate drainage, and roofs constructed with sufficient structural strength to support water ponded to level of a secondary roof drainage system. For existing sites with a significant risk of flooding, dikes, levees, and drainage features may be implemented; emergency action plans, flood recognition and early warning systems may allow operational response to flood events.

For example: flooding is not considered a credible event at the Rocky Flats Environmental Technology Site, due to the location, terrain, and meteorology, although inadequate roof and site storm drainage have resulted in local water damage in the past.

Wind

From a design basis standpoint, the design criteria impacted by sustained wind are pressure on walls and roofs, and the impact of wind-driven missiles.

In a extreme wind event, the impact on facilities from the pressures generated by the wind are lateral loading on structural surfaces and damage at corners and eaves (outward pressure on the downstream surface). In the event that the surface is breached (e.g. a door or window is broken, or a wind-driven missile penetrates), then interior pressure can develop causing other wall and roof surfaces (as well as interior walls) to be blown outward. Wind pressure may also cause problems with ventilation containment system pressure reversals.

The impact on facilities from wind-driven missiles must be calculated based on an assumed condition. For Performance Category 4 SSCs, the assumed missile criteria is a 2X4 timber plank, 15 lb. at 50 mph (horizontal), maximum height of 50 ft above ground.

Features of facilities commonly used to mitigate impacts of extreme wind are additional structural supports, additional anchoring for external features, cross-bracing on walls and ceilings, and reinforced concrete external walls. Dynamic analysis (vibration response spectra) may be required for taller, thinner SSCs.

For example: the design basis event for sustained wind at the Rocky Flats Environmental Technology Site is 161 miles/hour. Missile criteria is bounded by the tornado missile.

Tornado

From a design basis standpoint, the design criteria impacted by a tornado are pressure on walls and roofs, and the impact of wind-driven missiles.

In a tornado event, one impact on facilities from the pressures generated by the tornado winds are lateral loading on structural surfaces. This can generally be considered as translational force with no rotational component (the sum of the tornado rotational and translational velocities). Atmospheric pressure change (APC) between the vortex center and the radius of maximum wind can exert an outward force (suction) on walls and roofs causing other wall and roof surfaces (as well as interior walls) to be blown outward. APC may also cause problems with ventilation containment systems.

The impact on facilities from wind-driven missiles must be calculated based on an assumed condition. For Performance Category 4 SSCs, the assumed missile criteria are: a 2X4 timber plank, 15 lb. at 150 mph (horizontal), maximum height of 200 ft above ground, 100 mph (vertical); a 3 in. dia. steel pipe, 75 lb. at 75 mph (horizontal), maximum height of 100 ft above ground, 50 mph (vertical); and a tumbling 3000 lb. automobile, 25 mph.

Features of facilities commonly used to mitigate impacts of tornadoes are additional structural supports, cross-bracing on walls and ceilings, and reinforced concrete external walls. For “squat” facilities, static analysis is typically satisfactory, but dynamic analysis is required for taller, thinner SSCs.

For example: the design basis event for sustained wind at the Rocky Flats Environmental Technology Site is 161 miles/hour; no supplemental velocity is provided for tornadoes. Missile criteria are given above. For most plutonium facilities at Rocky Flats, the structural features needed to meet seismic requirements bound those needed to meet wind/tornado requirements.

Earthquake And/Or Other Seismic Events On Facilities

From a design basis standpoint, the design criteria impacted by a seismic event are the structural features necessary to prevent the collapse, loss of containment, or falling over of SSCs. Key differences are the impact of seismic requirements throughout the structure and the need for dynamic analysis of SSCs.

In a seismic event, the initiating event is lateral and vertical acceleration on a SSC. The probability/severity of seismic events are very location-specific, being much more frequent in areas of major faults. Within a general area, variation in immediate geology and foundation design will result in differing impacts on different SSCs. The impact of the seismic vibration or acceleration will be amplified from the movement of soil, with the amplification being generally less for SSCs with foundations closer to or attached to bedrock, and with larger and more rigid foundations. Within a larger structure amplification and damping of seismic vibrations will also occur, so SSCs located within that structure must be analyzed base on the local vibration spectra. Impact on the facility will be collapse of members and rocking and rolling of components. Interaction between SSCs must be considered from structural failing and falling, proximity, flexibility of lines an attached cables, flooding or exposure to fluids from ruptured vessels, piping systems and dams, and effects of seismically-induced fires.

Features of facilities commonly used to mitigate impacts of seismic events are evaluation of event probability and seismic dynamic modeling and analysis, which generally results in strengthening, stiffening, and buttressing structures or designs, and modifying foundations and siting of larger facilities. The general approach is to use a probabilistic basis to select the design load, and then use deterministic approaches to evaluate the permissible response levels and perform design calculations. For SSCs within a larger structure, method to mitigate seismic impacts are seismic qualification of purchased components, analysis of anchoring requirements, additional points of attachment, and other means of dampening modes of vibration. Single point failures must be analyzed. For existing facilities analyses must be performed as to their seismic risk. Remedying unsatisfactory conditions will be based on relative risk and intended length of future service.

Operational mitigation of seismic risk is provided by the facility safety analysis report, which will bound facility risks and conditions and set requirements on facility procedures, classification of components, allowable inventory, and similar operational parameters. Additional quality assurance of components and peer review of designs and modifications is required to assure as-built and ongoing facility risk.

For example: the design basis earthquake at the Rocky Flats Environmental Technology Site is nominally 0.24 g for Performance Category 4 SSCs; however, values for all facilities must be analyzed based on the requirements of DOE-STD-1023-95. The 94-3 Implementation Plan sets an ‘Evaluation Basis Earthquake’ for Building 371 at 0.25 g peak ground acceleration.

b. Describe the safety measures and design features commonly used as safeguards against natural hazards.

Safety measures and design features used to mitigate the effects of floods are:

- Siting of the SSC above the design basis flood;
- Dikes and levees to keep elevated waters away from the facility;
- Development of emergency implementation plans and early warning systems;
- Design of sites with adequate drainage for abnormal levels of precipitation;
- Design of secondary drainage systems to preclude problems from pluggage of primary drainage systems (roofs and local areas of sites); and
- Sealing and hardening of SSC to prevent water damage.

Safety measures and design features used to mitigate the effects of sustained winds are:

- Strengthening of surfaces of facilities to account for lateral and vertical wind loading;
- Design of facilities for internal pressures generated by extreme winds;
- Facility cladding and roofing to mitigate surface damage;
- Design for wind-driven missile damage; and
- Emergency plans and early warning systems to warn of and prepare for severe storms.

Safety measures and design features used to mitigate the effects of tornadoes are:

- Strengthening of surfaces of facilities to account for lateral and vertical wind loading, and APC conditions;
- Design of facilities for internal pressures generated by extreme winds;
- Facility cladding and roofing to mitigate surface damage;
- Design for wind-driven missile damage; and
- Emergency plans and early warning systems to warn of and prepare for severe storms.

Safety measures and design features used to mitigate the effects of earthquakes are:

- Siting of facilities in areas of low seismic activity;
- Modeling, designing and modifying facilities to withstand appropriate seismic loads;

- Developing safety analyses and adherence to operational requirements to assure that facilities operate within an adequate safety envelope; and
- Equipment qualifications, installation, internal design, and quality control to assure component performance.

c. Discuss the requirements related to earthquake load design that are stipulated in DOE Order 6430.1A, General Design Criteria, for Department of Energy facilities that handle, process, or store radioactive material.

The General Design Criteria specifies the following design requirements for new facilities handling, processing, or storing radioactive material:

- Section 0111-2.4: Wind loading shall be based on UCRL 53526, Rev. 1 wind speed and missile parameters;
- Section 0111-2.5 Tornado loads shall be based on UCRL 53526, Rev. 1 wind speed and missile parameters;
- Section 0111-2.7 Earthquake loads shall be based on UCRL 53582 requirements. Site specific hazards models shall be developed. Earthquake load design shall be according to procedures contained in UCRL 15910 (now superseded by DOE-STD-1020-94). Independent reviews of seismic design will be made for higher-risk facilities;
- Section 0111-99 Requirements to those above are delineated for Nonreactor Nuclear Facilities; and
- Section 200-1.1 Natural Hazards, including wind, hurricane, tornado, and seismic activity are required to be considered in the siting of facilities.

1.17 Construction Management and Engineering Personnel shall Demonstrate a familiarity level knowledge of the basic concepts of hydrology.

Supporting Knowledge and/or Skills

a. Define hydrology as it applies to construction management and engineering

Hydrology is the study of the occurrence and distribution of water, both on and under the earth's surface. Through hydrologic analysis, engineers are able to quantify the flow of water under a variety of circumstances, allowing them to safely locate and design structures in or adjacent to waterways. Hydrologic analysis is also used to study water supply, design remedial environmental cleanup, and develop environmental protection measures.¹ Hydrologic analysis will help the construction engineer to design appropriate water management controls that will divert surface water from the construction site, dewater the subsurface sufficiently to permit unimpeded movement of construction equipment, control construction related siltation, and take other measures that are necessary for successful construction related activities.

b. Describe the flow of subsurface groundwater.

Precipitation that infiltrates the soil and is not used by plant life migrates downward. The water passes essentially vertically through the vadose zone and ultimately reaches the water table. It may also get trapped temporarily in a perched water table. Once water has arrived at the water table, lateral movement down the hydraulic gradient occurs as does vertical mixing with existing groundwater in the aquifer. Groundwater may be thus transported great distances, over very long time periods. This water may be returned to the surface at varying distances from its point of infiltration by wells, springs, and direct recharge of surface waters.

If, in the process of moving from the surface to the groundwater aquifer, the water is contaminated by a hazardous substance, the moving water may become the transporting agent for the environmental contaminant. Vertical movement through the vadose zone creates one set of cleanup challenges; lateral movement in the aquifer creates a completely different set. Ultimately, the real risk to populations and ecosystems is when and if the hazardous substance is returned to the surface. Most cleanup technologies mitigate the risk of this reintroduction into the environment by removing the source of contamination and then by treating or isolating the impacted groundwater. The source of contamination may be located in the vadose zone or a non-aqueous phase liquid that is pooled on the water table or, if denser than water, within the groundwater.

¹ Potter, 1994, *Principles and Practices of Civil Engineering* 1st Edition, Great Lakes Press.

2.5 *Construction management and engineering personnel shall demonstrate a familiarity level knowledge of the following Department of Energy Technical Standards and Order related to natural phenomena hazards:*

- DOE-STD-1020-94, Natural Phenomena Hazards Design and Evaluation Criteria for Department of Energy Facilities
- DOE-STD-1021-93, Natural Phenomena Hazards Performance Categorization Guidelines for Structures, Systems, and Components
- DOE-STD-1022-94, Natural Phenomena Hazards Site Characterization Criteria
- DOE Order 5480.28, Natural Phenomena Hazards Mitigation

a. *Describe the purpose, scope, and application of the requirements detailed in the listed Technical Standards and Order.*

DOE-STD-1020-94

Purpose: This DOE Standard gives design and evaluation criteria for Natural Phenomena Hazards (NPH) effects as guidance for implementing the NPH mitigation requirements of DOE Order 420.1 and the associated implementation guides. It is intended to provide consistent design and evaluation criteria for protection against NPH at DOE sites throughout the United States.

Scope: The design and evaluation criteria presented by this standard are meant to control the level of conservatism introduced into the design/evaluation process such that earthquake, wind, and flood hazards are treated on a consistent basis. These criteria also employ a graded approach to ensure that the level of conservatism and rigor in design/evaluation is appropriate for facility characteristics such as importance, hazards to people on and off site, and threat to the environment. For each natural phenomena covered, these criteria consist of the following:

- Performance categories and target performance goals as specified in the DOE Order 420.1 NPH Implementation Guide and DOE-STD-1021;
- Specified probability levels from which NPH loading on structures, equipment, and systems is developed; and
- Design and evaluation procedures to evaluate response to NPH loads and criteria to assess whether or not computed response is permissible.

Application These criteria apply to the design of new facilities and the evaluation of existing facilities. They may also be used for modification and upgrading of existing facilities as appropriate. The application of NPH design requirements to structures, systems and components (SSCs) shall be based on the life-safety or the safety classifications for the SSCs as established by safety analysis.

DOE-STD-1021-93

Purpose: This DOE Standard gives design and evaluation criteria for NPH for selecting performance categories (PCs) of SSCs in accordance with the requirements specified in DOE order 420.1 and the associated implementation guides. It also recommends procedures for consistent application of the determined PC criteria so that the DOE review and approval process is simplified.

Scope: The criteria and recommendations presented in this standard shall apply to performance categorization of SSCs for the purpose of mitigating natural hazards phenomena in all DOE facilities covered by DOE Order 420.1.

Application: The provisions of this standard apply only to NPH evaluation of SSCs. Application of basic categorization guidelines presented in this standard will establish the preliminary performance category of SSCs. The procedural steps presented are general recommendations for NPH performance categorization only, and are not intended to provide procedures for performing facility safety reviews or accident analyses.

DOE-STD-1022-94

Purpose: This DOE Standard provides criteria for site characterization to provide site-specific information for implementing the requirements of DOE order 420.1 and the associated implementation guides. Additionally the purpose of this standard is also to develop a sitewide database related to NPH that should be obtained to support individual safety analysis reports (SARs). Appropriate approaches are outlined to ensure that the current state-of-the-art methodology is being used in the site characterization.

Scope: The criteria and recommendations in this standard shall apply to site characterization for the purpose of mitigating NPH in all DOE facilities covered by DOE Order 420.1. Criteria for site characterization not related to NPH are generally not included in this document unless they are deemed necessary for clarification. General and detailed site characterization requirements are provided in the areas of meteorology, hydrology, geology, seismology and geotechnical studies.

Application: The criteria and recommendations in this standard shall apply to site characterization for the purpose of mitigating the effects of NPH in all DOE facilities covered by DOE Order 420.1.

DOE Order 5480.28

This Order has been cancelled and replaced by new Order **DOE O 420.1, Facility Safety**, effective 10-13-95. For the purpose of this study guide the new order will be discussed.

Purpose: This order established facility safety requirements related to: nuclear safety design, criticality safety, fire protection and natural hazards mitigation. Natural NPH

Mitigation is covered in detail in section 4.4 of the Order. With regards to NPH, the order provides requirements to ensure that all DOE facilities are designed, constructed, and operated so that the general public, workers, and the environment are protected from the impact of NPH. The provisions of section 4.4 cover all NPH such as seismic, wind, flood and lightning.

Scope : The Order includes provisions for general design requirements, NPH mitigation design requirements, evaluation and upgrade of existing DOE facilities, NPH assessment, natural phenomena detection, and post-natural phenomena procedures.

Applicability: The NPH mitigation requirements are applicable to DOE facilities including the following: new nuclear, new non-nuclear, existing nuclear, existing non-nuclear, modifications to nuclear, modifications to non-nuclear, accelerators and fusion facilities, and new, existing and modifications to weapons facilities. Facility and applicability requirements are defined on attachment 1, Table 1.

- b. Discuss the graded approach process that Department line management uses to determine an appropriate level of coverage by construction managers. Include in this discussion the factors that may influence the level of coverage.***

DOE Order 420.1 and the associated Implementation Guides establish a graded approach in which NPH requirements are provided for various performance categories, each with a specified performance goal. The graded approach enables design or evaluation of DOE SSCs to be performed in a manner consistent with their importance to safety, importance to mission, and cost. The graded approach enables cost-benefit studies and establishment of priorities for existing facilities. Probabilistic performance goals enable the development of consistent criteria both for all natural phenomena hazards and for all DOE facilities which are located throughout the United States.

Five performance categories are specified for the design/evaluation of DOE SSCs for NPH ranging from 0 through 4 as follow:

- (0) No safety, mission, or cost considerations;
- (1) Maintain Occupant Safety;
- (2) Occupant safety, continued operation with minimum interruption;
- (3) Occupant safety, continued operation, hazard confinement; and
- (4) Occupant safety, continued operation, confidence of hazard confinement SSCs are to be placed in categories in accordance with DOE-STD-1021-93.

Quantitative performance goal probability values are applicable to each NPH (earthquake, wind, and flood) individually. DOE-STD-1020-94 provides earthquake and flood design and evaluation criteria for the DOE. Appropriate performance goals are set for each performance category SSC.

Coverage by Construction Management resources may be effectively assigned utilizing the evaluation approach for an existing SSC as defined in DOE-STD-1020-94. That process includes the following elements:

- Collect design documents, conduct Site visit & operator interviews. Note differences between design & as-is condition. Determine performance categories for SSCs. Calculate as-is NPH capacity/demand by DOE-STD-1020;
 - If criteria are met, the SSC is adequate for natural phenomena hazards;
 - If criteria are not met, alternate options must be considered;
 - Upgrade easy-to-remedy deficiencies or weaknesses;
 - If upgrades are sufficient, SSC is adequate for NPH;
 - If close to meeting criteria, reevaluate using hazard probability of twice the recommended value;
 - If unsuccessful, conduct more rigorous evaluation removing added conservatism introduced by initial evaluation methods;
 - If successful, SSC is adequate for NPH; and
 - If unsuccessful and a backfit analysis indicates more work is necessary, strengthen SSC sufficiently to meet DOE-STD-1020 or change the usage of the SSC to a category with less stringent requirements.
- c. ***Determine contractor compliance with the documents listed above as they apply to contract design requirements and construction activities of a construction project at a defense nuclear facility.***

Natural Phenomena Hazards Mitigation- The contractor is responsible to ensure that all DOE facilities are designed, constructed, and operated so that the general public, workers, and the environment are protected from the impact of NPH. The provisions of this requirement apply to DOE sites and facilities and they cover all natural phenomena hazards such as seismic, wind, flood, lightning. Where no specific requirements are specified, model building codes or national consensus industry standards shall be used.

General Requirements- For hazardous facilities, safety analyses shall include the ability of SSCs and personnel to perform their intended safety functions under the effects of natural phenomena.

Natural Phenomena Mitigation Design Requirements SSCs shall be designed, constructed and operated to withstand the effects of natural phenomena as necessary to ensure the confinement of hazardous material, the operation of essential facilities, the protection of government property, and the protection of life safety for occupants of DOE buildings. The design process shall consider potential damage and failure of SSCs due to both direct and indirect natural phenomena effects, including common cause effects and interactions from failures of other SSCs. Furthermore, the seismic requirements of Executive Order 12699 shall be addressed.

SSCs for new DOE facilities, and additions or major modifications to existing SSCs shall be designed, constructed and operated to meet the requirements in the previous paragraph. Any additions and modifications to existing DOE facilities shall not degrade the performance of existing SSCs to the extent that the objectives in this Section cannot be achieved under the effects of natural phenomena.

Evaluation and Upgrade of Existing DOE Facilities SSCs in existing DOE facilities shall be evaluated when there is a significant degradation in the safety basis for the facility. Furthermore, the seismic requirements of Executive Order 12941 shall be addressed.

If any of the conditions above are satisfied then the contractor/operator shall establish a plan for evaluating the affected SSCs. The plan shall incorporate a schedule for evaluation taking into account programmatic mission considerations and the safety significance of the potential failure of SSCs due to natural phenomena.

If the evaluation of existing SSCs identifies natural phenomena mitigation deficiencies, the contractor/operator shall establish an upgrade plan for the affected SSCs.

The upgrade plan shall incorporate a prioritized schedule for upgrading the SSCs. The upgrade plan shall address possible time or funding constraints as well as programmatic mission considerations.

Natural Phenomena Hazards Assessment The design and evaluation of facilities to withstand natural phenomena shall be based on an assessment of the likelihood of future natural phenomena occurrences. The NPH assessment shall be conducted commensurate with a graded approach and commensurate with the potential hazard of the facility.

For new Sites; NPH assessment shall be conducted commensurate with a graded approach to the facility. Site planning shall consider the consequences of all types of NPH. For existing Sites; if there are significant changes NPH assessment methodology or site-specific information, the NPH assessments shall be reviewed and shall be updated, as necessary. A review of the NPH assessment shall be conducted at least every 10 years. The review shall include recommendations to DOE on the need for updating the existing NPH assessments based on identification of any significant changes in methods or data.

Natural Phenomena Detection Facilities or sites with hazardous materials shall have instrumentation or other means to detect and record the occurrence and severity of seismic events.

Post-Natural Phenomena Procedures Facilities or sites with hazardous materials shall have procedures that include, inspecting the facility for damage caused by severe natural phenomena, and placing the facility into a safe configuration when such damage has occurred.